Scientific River Basin Management

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INTRODUCTION

In late summer 1992 after several years of drought, significant precipitation returned to much of the Upper Mississippi River Basin (UMRB). This rain and snow continued over the eastern parts of the basin for the rest of the year and saturated the soil. By late spring 1993, the soil was saturated, and precipitation in the area had increased considerably. In fact, during June through September 1993, parts of Iowa, Kansas, and Missouri received more than twice the normal precipitation for the period. This resulted in devastating flooding on the floodplains of the lower Missouri River, upper Mississippi River, and Illinois River, and on many tributaries and much of the upland areas as well. Some people thought at the time that this flood was extremely rare, probably with a recurrence interval of 500 years. However, examination of the hydrologic data by the U.S. Geological Survey (USGS) and others showed that while the flooding was record setting in many areas, in others it ranged between a 0.10 and 0.01 percent chance of occurrence per year. This relates to a 10- year to 100-year flood, using common terminology. In fact, flooding in some upland areas was less severe than in others, and the unusual duration and areal extent caused main-stem flooding generally to be more severe than tributary and upland flooding.

The administration recognized the need to make scientific information readily available to planners, managers, and policy makers in the basin area. To acquire and begin analyzing the data, the Scientific Assessment and Strategy Team (SAST) was established on November 24, 1993. The (SAST 1994) was directed to lead this interdisciplinary, interagency team made up of members from the U.S. Army Corps of Engineers , Environmental Protection Agency, Federal Emergency Management Agency (FEMA), Fish and Wildlife Service (FWS), National Biological Survey , and Soils Conservation Service. Another task of SAST was to provide scientific support to the Interagency Floodplain Management Review Committee (FMRC 1994) that was established to analyze policy alternatives for the management of the Upper Mississippi River Basin.

The goal of the SAST was to provide scientific advice and assistance to Federal officials responsible for making decisions about flood recovery in the basin and to provide information regarding both nonstructural and structural approaches to river basin management. The objectives of the SAST were as follows:

- to develop a data base of readily available data to support map production, scientific analysis, and decision making;
- to produce maps showing base information and vulnerability to flooding; and
- to prepare reports documenting the products of the SAST and the methods and analysis used to produce them, and identifying the ongoing monitoring, research, modeling, data management, and distribution requirements needed to support integrated river basin management.

This report discusses, at a general level, the major findings of the SAST and a strategy to more effectively incorporate scientific information into river basin management.

MAJOR FINDINGS OF THE SAST

o Floods of the magnitude of the 1993 Mississippi flood have occurred in the past and will probably occur again in the future. While flooding set records in many areas in 1993, in others the flooding reached only 10- to 100-year levels. In general, the flooding was more severe on main-stem floodplains than in tributaries.

o Although human action did not cause the floods of 1993 , human activities in the uplands and on the floodplains had a major effect on the flood's impacts. For instance, the location of some levees increased sedimentation and scour.

o The floodplains are highly productive agricultural areas. Some of these areas benefited from the flood, although agriculture in most floodplain areas was harmed during 1993. The uplands are also highly productive agricultural areas. Most upland areas were fully saturated during 1993, resulting in reduced crop output and significant runoff that accumulated as floods.

o Three major regions in the floodplain that respond in different ways to flooding.

(1) **Active high-energy floodplain**, which lies adjacent to today's rivers. This region experienced deep flooding with swiftly flowing currents and also contained extensive areas of scour and sand deposition. For example, moderately thick to thick sand deposits covered more than 50 percent of the active high energy floodplain in the narrow bottomland areas along the Missouri River.

(2) **Low energy floodplain**, which is formed of river terraces that represent a higher, older level of the rivers. These areas experienced flooding of 3 to 10 feet and had far fewer and less extensive areas of scour and deposition. For example, moderate to thick flood deposits covered less than 3 to 5 percent of the floodplain along these reaches of the Missouri River.

(3) **Highest river terraces**, which were not flooded in 1993.

o Levee breaches along the lower Missouri River generally resulted in high-velocity flows, causing extensive scour and sand deposition. By contrast, levee breeches along the middle Mississippi River generally resulted in passive inundation of bottomland tracts. However, even on the middle Mississippi River some areas of significant sedimentation and scour occurred. On the lower Missouri River, 72% percent of the levee breaches occurred where the new river crossed a historic river channel less than 100 years old age.

o Natural wildlife habitat in the floodplains of the lower Missouri and Illinois Rivers has decreased greatly over the past century. This has caused a severe reduction of fish species in the area and a corresponding reduction in commercial fishing. Preliminary evidence indicates that the flood provided significant ecological benefits. Flood-created scour areas contain abundant and diverse fishes. For example, following the flood, several young-of-the-year blue suckers (a candidate for Federal endangered species listing) were collected and may represent the first documented evidence of blue sucker reproduction in the middle Mississippi River. Birds also are using newly created wetland habitats.

o Wetlands restoration not only can improve water quality from agricultural watersheds but also can provide habitat for wildlife and, to some extent, reduce downstream flooding, particularly during the smaller, more frequent storms. Watersheds with large amounts of wetland in the upland can experience an appreciable reduction in smaller floods, but wetlands may not have had an appreciable effect on floods of such magnitude as the 1993 flood.

o Converting land into conservation reserves, using conservation tillage, creating wetlands, and employing other landuse strategies can reduce flooding, but proper strategies vary depending on the topography, soil type, and other features of the watershed. Not all land use practices are applicable everywhere.

o Private levee systems along the Missouri River were placed as close to the river as possible, and for the most part do not allow for the recommended floodway (Ferrell, 1993). A 1991 study for the FEMA (Hall, 1991) showed that agricultural levees had little effect on flood stage for 100-year floods on the Missouri River from Waverly to Jefferson City, Mo, because the relatively low levees would overtop during major flood events -- which is exactly what happened in 1993. Many districts with levees designed for high-magnitude floods have been flooded between 5 and 10 times during the past 50 years, a history that reflects poorly on the location and the design capacity of many of these levees.

o For a flood of the magnitude and duration of the 1993 flood, the levees had little systemwide impact. However, areas where levees were breached or overtopped often experienced major flood damages. Within the reach from Glasgow to St. Louis (about 225 river miles), approximately 5 to 7 percent of the floodplain (13,000 to 18,000 acres) was substantially damaged as a result of the levee breaches.

o Considerable amounts of data needed to manage the rivers of the upper Midwest are available at all levels of government and in many nongovernment agencies. To help ensure that data collected in the future can be used broadly, the SAST recommended that all data gathered by agencies be maintained in commonly accepted data exchange formats established by the Federal Geographic Data Committee (FGDC) . A data clearinghouse will be established at the Earth Resources Observation Systems (EROS) Data Center (EDC) of the USGS. However, additional data and information are needed on specific issues such as future levee placement, habitat restoration, and monitoring the effects of human activities on the landscape.

STRATEGY

The findings of the SAST show clearly that using additional scientific information when making decisions could help reduce the impact of floods. Scientific information and advice are important to the effective and economical management of the river basin. Such information and advice must be derived from a well-coordinated plan of activities that incorporates baseline information, detects changes to the system, determines the effects of changes, improves methods of predicting changes, and makes the knowledge available to the user community.

BASELINE INFORMATION (MAPPING)

Many Federal and non-Federal organizations have produced or are producing information on the physical, biological, cultural, and economic aspects of the environment, as well as information about the processes taking place in the environment. This information must be related to the location where phenomena exist or processes take place. The SAST has developed a data base that incorporates a considerable amount of data, such as: Landsat thematic mapper images before, during, and after the flood; extent of flooding for the 1993 flood; transportation network; period-of-record daily flow for 50 long-term USGS stations; period-of-record peak-flow for 154 sites in the flood area; daily reservoir storage; climate; daily precipitation; land use and land cover; point locations of sightings of rare and endangered species; North American Waterfowl Plan Joint Venture areas; resource inventories of floodplain and ecological variables for some river reaches; ownership of wildlife refuges in the floodplains; critical infrastructure; superfund sites; permitted dischargers; public water systems; levee locations, ownership, physical information, and historic breaches; historic channel and land use conditions; and limited economic information.

Although this data base is large and varied, there are still categories of data for which baseline information is not available or is not available at a fine enough resolution for site-specific decisions and, in some cases, for systemwide modeling. Therefore, the baseline data set must be completed for many categories of data. In most cases, programs exist within the Federal Government or State agencies to obtain necessary baseline information. In some cases, nongovernment organizations should be involved as well.
Specific data requirements have been identified by the SAST.

MONITORING

A monitoring program should be established to continually evaluate the response of the system to policies and management techniques . A number of themes should be monitored. These include land cover; ecological indicator species, communities, and biological processes; channel changes; structural and nonstructural flood control features; flood flows, stages and other characteristics; location and condition of toxic materials and dynamics of toxics dispersal by hydrologic and hydraulic means; economic characteristics; and social and cultural dynamics.

Here too, programs are in place to monitor some of these variables. Closer coordination and some refocusing would help ensure that an adequate integrated monitoring system is in place. The benefits would be early detection of problems within the system, which then could be acted on before more costly, larger changes had to be made at a later date.

ANALYSIS

The SAST conducted its activities in an interdisciplinary atmosphere that led to findings and new understanding that would not have taken place if each of the disciplines had worked independently. Such interdisciplinary analysis should be instituted as the norm rather than the exception. Various specific analyses should provide the basis for integrated river basin management. The analyses can be characterized broadly as (1) regionalization, (2) process studies (systemwide, uplands, and floodplains),and (3) engineering and design.

(1) It is important to identify hydrologic response units (HRU) and ecologic response units (ERU) on the basis of several variables in the region. Both HRU's and ERU's are necessary for modeling the system's response to various forcing functions and for feedbacks to determine how system components affect one another.

(2) Additional studies necessary to support decision making include the following: the effects of various land treatment practices on the hydrologic and ecologic response in the uplands and in the floodplains; the effects of fluvial processes, surficial geology, floodplain geomorphology, and topography on the performance and integrity of levees; the effects of various land uses and covers on flood characteristics; the relationship between precipitation events, upland floods, floodplain floods, and low flows; identifying the sources, sinks, and transport of nutrients and toxins; the diffusion of disease during flood events; and the social impacts of floods.

(3) Engineering and design can be enhanced by studying the alternative design and (or) placement of levees, retention structures, and nonstructural flood control mechanisms to determine the effects of the physical environment on their integrity. These studies include testing for the effects of surficial geology , floodplain and channel way morphology, topography, and the proximity to existing infrastructure on alternative flood control structure designs. In addition study is needed on how levee breaches are related to historical channel ways, and to land covers on buffer zones, on floodways, and elsewhere on the floodplain. Examine alternative design of levees, retention structures, impoundment channel, control structures, and nonstructural flood control mechanisms to determine methods for adapting to the physical environment while operating in harmony with the cultural and biological environments.

MODELING

Three types of models are important for river basin management. They are ecological and hydrologic models of the river basin and advanced hydraulic models of the floodways of the main stems and major tributaries. A conceptual ecological model of how the environment and the various species within it interact should be developed. Man should be included as one of the species. Such a model should be able to predict the qualitative changes in ecological variables as the Upper Mississippi River Basin system evolves because of human activity and natural changes. This would require basic as well as applied research. As experience is acquired with a qualitative conceptual model, variables can be quantified and a quantitative numerical model can begin .

It is also important to develop a functioning hydrologic model of the Upper Mississippi River Basin at a broad scale to help predict the changes taking place within the water systems of the basin. This is important both for the ecological modeling and for better understanding of how changes in the system are affecting the natural distribution of water through the system. This type of model would be valuable for flood prediction.

Hydraulic modeling should be improved for the main stems of the upper Mississippi, lower Missouri, and Illinois Rivers and for the major tributaries. This is important not only for predicting floods but also for testing the effects of alternative structural and nonstructural methods of flood control. In the short run, a sophisticated one-dimensional model can be expanded throughout the major floodplains. Two-dimensional models of critical areas, such as confluences of rivers, major obstruction areas, and significant changes in floodplain morphology, should be embedded in the one-dimensional model. As the modeling techniques are refined and appropriate digital elevation data become available, the two-dimensional hydraulic model should be expanded, ultimately covering the major floodplains.

These models should be integrated and should link technologies such as remote sensing, geographic information systems, time-series analysis, and visualization, to ensure the rapid entering and processing of data and the effective presentation of the resulting information.

DATA MANAGEMENT AND DISTRIBUTION

Organizations at all levels of government and outside of government should maintain data on the variables that are important to them. These data should be maintained at the appropriate scale and accuracies and in generally accepted exchange formats, such as the Spatial Data Transfer Standard. The data should adhere to FGDC metadata standards. Wherever possible, data should be readily accessible in computer-readable files. This is important to ensure interchangeability and intercomparability for coordinated decision making among different levels of government and in different locations. It is also critical for rapid response in times of emergency.

These digital data should be available through a distributed clearinghouse as part of the National Information Infrastructure. The clearing house should be accessible online through a commonly used network such as the Internet. A central responsibility for high level clearinghouse architecture should exist. Data should be available online and offline. Such a clearinghouse is being established at the USGS Sioux Falls, S. Dak. Much SAST data are available online over the Internet, with additional data available offline. As data are prepared in the proper format, they will be made available. The FWS's National Wetlands Inventory has been linked to the clearinghouse. Discussions have begun with other Federal agencies, States, and county- level governments about becoming linked to the clearinghouse . Discussions with nongovernment organizations are planned.

The SAST data base can be accessed on the Internet by using Mosaic software. Mosaic users can access SAST data with the following Uniform Resource Locator

http://edcwww.cr.usgs.gov/sast-home.html

For users who do not have Mosaic but have access to Internet, the necessary Mosaic software (freely distributed for Unix, PC, and Macintosh platforms) can be acquired by using anonymous File Transfer Protocol as follows:

ftp.ncsa.uiuc.edu

A limited number of data sets will be available initially. As data sets become quality assured and documented, they will be made available.

SCIENTIFIC COORDINATION

A coordinating body of scientists should be established to review programs of scientific research and data collection at various levels of government and to advise Federal, State, tribal, and local governments and nongovernment organizations on the scientific activities that could support the management of the Upper Mississippi River Basin. These scientific interdisciplinary bodies should be established at three levels:

(1) An advisory group should be composed of scientists in various disciplines from Federal and non-Federal government agencies and the private sector. The first activity of this group should be to evaluate agency programs and do a budget crosscut of the scientific and data gathering activities river basin management and emergency response. The evaluation will identify gaps and overlaps and help develop a program to correct deficiencies and eliminate duplication. The scientists in this group would serve as principal scientific advisors to the River Basin Commissions, the Water Resources Council, and other management entities. They would work part time, with members funded by their home organization's, convening to conduct crosscuts of scientific activities and to give advice. These should be senior-level scientists with direct

links to the decision-making apparatus in their organizations.

(2) A multidisciplinary group of scientists from various agencies and levels of government should be established to maintain cognizance of science and data acquisition and to develop analytical and management techniques for use by managers and scientists in the river basin. Some members of this group will respond rapidly during and after flood events to gather information useful for flood prediction, design of flood control or mitigation mechanisms, or improved response to flooding. This group will also support the integration of data acquisition and distribution. These working-level scientists should maintain links with the FGDC, the National Advanced Remote Sensing Applications Program, and other agencies and interdisciplinary coordinating and research activities.

(3) A disaster response group should be established to assist in the use of scientific information during times of emergency. This team could be a subset of the analysis group. Members should be well-versed in the science, data, and technologies relevant to disaster response and recovery. This group should be led by FEMA.

CONCLUSION

The SAST concentrated its efforts on a particular topic, floods, in a particular region, the Upper Mississippi River Basin, and thus selected variables for inclusion in the data base and for analysis that are relevant to that topic and region. Certainly, some of those variables are relevant to many other topics as well, but those topics would include additional variables not contained in this data base. Topically relevant variables readily available through a clearinghouse can be useful in planning for and responding to disasters and other social and environmental problems. The activities of the SAST were conducted in a short time in response to a disaster. Planning ahead for these disasters and establishing coordinating organizations should help reduce the impacts of disasters on the Nation.

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